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ABSTRACT

THE ASSOCIATION BETWEEN PERIODONTAL DISEASE AND METABOLIC SYNDROME AMONG UNITED STATES ADULTS: ANALYSIS OF NHANES 2013-2014.

By

BRENDA RUIZ

APRIL 2019

INTRODUCTION: Studies support a bidirectional relationship between periodontal disease and metabolic syndrome (MetS). In addition to sharing risk factors, it is believed they also share a pathologic role in the development or progression of cardiovascular disease (CVD). The present article presents an overview of the evidence linking periodontitis with selected systemic diseases and calls for increased cooperation between medical and oral healthcare providers to provide optimal screening, treatment, and prevention of both periodontitis and its comorbidities.

AIM: This study aims to understand (a) the relationship between periodontal disease and metabolic syndrome and (b) the associations between periodontal disease and the components comprising metabolic syndrome (hypertension, reduced HDL cholesterol levels, elevated triglyceride levels, abdominal obesity, and elevated blood glucose levels) using the National Health and Nutrition Examination Survey data.

METHODS: A cross-sectional analysis of the 2013-2014 National Health and Nutrition Examination Survey (NHANES) data was conducted to assess the associations between periodontal disease, metabolic syndrome, and the components comprising metabolic syndrome. Participants aged ≥ 30 years were eligible. Periodontal disease was defined using the Centers for Disease Control and Prevention- American Academy of Periodontology (CDC-AAP) guidelines and metabolic syndrome was defined using the International Diabetes Federation (IDF) criteria. The adjusted odds ratios of periodontal disease were calculated controlling for variables fitted using logistic regression. Data were assembled and analyzed using SAS 9.4 (Statistical Analysis System, Cary, NC, USA).

RESULTS: For both MetS and periodontal disease, statistically significant associations were observed in all of the selected participant demographic characteristics. Despite existing evidence suggesting a bidirectional relationship between periodontal disease and MetS, and positive associations between periodontal disease and the five metabolic risk factors that comprise MetS, no statistically significant associations could be determined in this analysis.

DISCUSSION: The purpose of this analysis was to explore the associations between periodontal disease, MetS, and the five metabolic risk factors (hypertension, reduced HDL cholesterol, abdominal obesity, elevated blood glucose levels, and elevated triglycerides) among the United States' adult population. By understanding the risk factors associated with systemic diseases we are able to better target at-risk population groups, improve health and healthcare, and advance health equity.

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UNITED STATES ADULTS: ANALYSIS OF NHANES 2013-2014.

by

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B.S., GEORGIA STATE UNIVERSITY

A Thesis Submitted to the Graduate Faculty
of Georgia State University in Partial Fulfillment
of the
Requirements for the Degree

MASTER OF PUBLIC HEALTH

ATLANTA, GEORGIA
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APPROVAL PAGE

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Acknowledgments

I would like to express my sincere appreciation to my thesis committee chair Dr. Harry J. Heiman, for his expertise, assistance, guidance, and patience throughout the completion of this thesis. I am also immensely grateful to my committee member, Dr. Ruiyan Luo, for her important comments and informative views on the issues related to my research question and study design. Without their support and invaluable constructive criticism, this analysis would not have been possible.

I would also like to extend my sincere gratitude to the exceptional faculty and staff of the School of Public Health for their guidance and support throughout the program. Last but not least, I am gratefully indebted to my family and friends for their unwavering support.

Author's Statement Page

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Brenda Ruiz
Signature of Author

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Chapter I-Introduction

1.1 Background

In the United States today, chronic diseases are among the most prevalent and costly health conditions, leading to hospitalization, long-term disability, reduced quality of life, and death.¹⁻⁴ Despite having relatively poor health outcomes; the US, leads in health care spending. This is largely due to the rising number of Americans living with chronic diseases.^{1,2} There are a number of factors driving the increase in people living with chronic medical conditions. A lack of universal health insurance and poor access to primary care contribute to inadequate prevention, detection, and management of chronic diseases. At the same time, an aging and increasingly overweight and obese population, in part due to social, economic, and environmental factors that create barriers to affordable healthy lifestyle choices have also enabled more sedentary and unhealthy behaviors, furthering the rise in chronic diseases.⁵ According to the Centers for Disease Prevention and Control (CDC), the current burden of six in ten Americans suffering from at least one chronic disease is expected to rise as competing priorities, limited resources, and misuse and overuse of medical care continue to drive the prices of labor, pharmaceuticals, and administrative costs upward.³

Cardiovascular disease (CVD) is one of the most prevalent chronic diseases affecting Americans and the leading cause of death worldwide.^{6,7} CVD includes a range of disorders that affect the body's blood vessels and the heart's structure and function.⁷ Risk factors for CVD include hypertension, abnormal cholesterol levels, and elevated blood glucose levels. One clearly identified cluster of conditions that increases the risk of CVD is called metabolic syndrome (MetS).⁸

MetS includes five core components, all of which are known metabolic risk factors for CVD. These include: abdominal obesity,^a elevated triglycerides,^b reduced HDL cholesterol,^c hypertension,^d and elevated fasting blood glucose.^{e, 9,150} What is particularly alarming about MetS is that in addition to increasing the risk of CVD, each component of this syndrome also increases the risk for progression of other chronic diseases like type 2 diabetes, results in deteriorating disabilities, and poses an indirect economic burden, among others.^{11,12} According to the CDC, the prevalence of MetS is estimated at greater than 30% in the U.S. and has substantially increased since 1988.¹¹⁻¹³ Other risk factors associated with MetS and increased risk of CVD include oral diseases, and more specifically periodontal disease.^{14,15}

Periodontal disease, a condition found in over 47% of U.S. adults, is strongly associated with risk for CVD, independent of traditional CVD risk factors.^{14,15} Periodontal disease or periodontitis is a chronic inflammatory condition of the gums, caused by naturally-occurring bacteria found in the mouth.¹⁶ Like other biofilm infections,^f it is resistant to antibiotic agents and host defenses due to the complex communities the microbes form. Without treatment and adequate preventive care, periodontitis affects the bone and supporting tissue, leading to the formation of pockets or spaces between the teeth and gums, that eventually lead to sore, bleeding gums, temporomandibular joint (TMJ) disorders, premature tooth loss, and other health conditions.^{16,17} Several reports have shown that treating the symptoms of periodontitis and managing its progression have helped with the management of other chronic conditions,

^a Abdominal obesity: Waist circumference ≥ 102 cm in males or ≥ 88 cm in females

^b Elevated Triglycerides: ≥ 150 mg/dL

^c Reduced HDL Cholesterol: reduced HDL cholesterol: < 40 mg/dL in males or < 50 mg/dL in females

^d Hypertension: Systolic BP ≥ 130 or diastolic BP ≥ 85 mm Hg

^e Elevated fasting plasma glucose: (FPG) ≥ 100 or oral glucose tolerance test (OGTT) ≥ 100 mg/dL

^f Biofilm Infection: a thin, slimy film of bacteria that adheres to a surface

including diabetes, heart disease, osteoporosis, respiratory disease and cancer.¹⁷ Because periodontal care is not commonly covered under health insurance, preventive care and early treatment is often delayed. As a result, periodontitis may go undetected until symptoms worsen in advanced stages.¹⁴⁻¹⁷

There is increasing recognition of the important relationship between different chronic diseases and that they do not exist in isolation.³ This is especially true for the relationships between oral health and physical health. Improving our understanding of these relationships is critical to informing both preventive approaches and integrating oral health care strategies into chronic disease prevention and management.

1.2 Research Aims and Hypotheses

This research will evaluate the extent to which metabolic syndrome and the five metabolic risk factors comprising MetS are associated with periodontal disease in the U.S. adult population using data collected from the 2013-2014 National Health and Nutritional Examination Survey (NHANES).

This study aims to understand:

Aim 1: Assess the association between metabolic syndrome and periodontal disease.

Hypothesis 1: There will be statistically significant associations between metabolic syndrome and periodontal disease.

Aim 2: Assess the associations between each of the conditions that comprise metabolic syndrome (hypertension, reduced HDL cholesterol, abdominal obesity, elevated triglyceride, and blood glucose levels) and periodontal disease.

Hypothesis 2: There will be statistically significant associations between periodontal disease hypertension, reduced HDL cholesterol, abdominal obesity, elevated triglyceride, and elevated blood glucose levels.

Chapter II-Literature Review

2.1 Periodontal Disease and MetS

Although largely preventable, dental caries and periodontal disease pose the greatest threat to oral health, and are among the most prevalent chronic diseases in the U.S.^{18,19} Without timely and appropriate treatment, they can result in complications including, oral pain, dysfunction, abscess formation, premature edentulism, and others.¹⁸ Evidence of possible associations between chronic oral infections and systemic disorders is widely supported, such that, the association between periodontal disease and systemic disorders has led to the evolution of periodontal medicine.^{g,18,20,21}

Studies support a bidirectional relationship between periodontal disease and MetS. In addition to sharing risk factors, it is believed they also share a pathologic role in the development or progression of CVD.^{7,8,10,20,22-29} In a cohort study conducted by Morita et al., of 1,023 adult employees who were followed for 4 years, they demonstrated a significant association between the presence of periodontal pockets and the development of one or more MetS components (OR: 1.6; 95% CI: 1.1 to 2.2).²² In another study, using a nationally representative sample, D'Aiuto et al. observed that the diagnosis of MetS increased among individuals with periodontal disease.²³ Moreover, the results showed a significant association between the severity of periodontal disease and the likelihood of also having MetS.²³ The prevalence of MetS was 18% (95% CI: 16-19) in those with no/mild periodontitis compared with 37% (95% CI: 28-48) in those with severe periodontitis.²³ A longitudinal study by Nesbitt et al., also demonstrated the association between

^g Periodontal Medicine: a branch of medicine dedicated to the study of the dynamic relationship between periodontal diseases and systemic conditions

periodontal disease and MetS; participants with periodontal disease were significantly more likely to possess components of MetS (OR 2.61, 95% CI 1.1-6.1, $p < 0.05$).²⁵

Studies also support the relationship between the severity of periodontal disease and the degree of MetS. In a multivariate analysis of 584 Japanese women, persons exhibiting more components of MetS had a significantly higher likelihood of having a greater pocket depth and clinical attachment loss— indicating more severe periodontal disease— than those with no components.²⁶ In a European study with 2,050 participants, MetS was associated with deepened periodontal pockets and carious teeth.^{27,28} In addition, a study of 941 adolescents suggested MetS components may be determinants for future periodontal diseases.²⁹ Based on the study results, having more components of MetS showed a significant positive correlation with gingivitis and other periodontal problems.²⁹ Those with one component of MetS had an OR of 1.88(95% CI: 1.28–2.76), compared with 3.29 (95% CI: 1.24–8.71) in those with three or more MetS components.²⁹

Research also demonstrates that MetS and periodontal disease are linked through a common pathophysiological pathway. A meta-analysis by Lamster and Pagan evaluated the evidence regarding this relationship.⁸ Their review found that both conditions can be attributed to oxidative stress, resulting in a low grade systemic inflammatory condition and increasing the risk of CVD.⁸ According to the study, individuals with periodontal disease, MetS, or a combination of both showed elevated levels of circulating inflammatory markers. These findings are further supported by additional studies that implicate inflammatory cytokines and other mediators produced in the periodontal lesion in regard to their capacity to impact tissues and organs distant from the oral cavity.^{20,30-35} Systemic disorders associated with the inflammatory response

include; diabetes mellitus, myocardial infarction, and endothelial dysfunction, among others.³⁰⁻

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In addition to the relationship between periodontal disease and MetS, research also indicates that there are relationships between periodontal disease and the individual metabolic risk factors that make up MetS, as discussed below.

2.2 Periodontal Disease and Abdominal Obesity

Obesity is characterized by abnormal or excessive deposition of fat in the adipose tissue and is a chronic disease with a multi-factorial etiology.^{20,36} If unaddressed, obesity can lead to adverse health outcomes and the secretion of cytokines and hormones involved in the pathophysiology of related systemic diseases.³⁶ For instance, prevailing data suggests that both obesity and MetS are immediate precursors of diabetes mellitus and CVD.^{20, 30-35} Now, further evidence suggests obesity is involved in regulating the onset and progression of periodontitis, due to the impact it generates on the metabolic and immune parameters of the host.^{20,35-39} Juárez et al., performed a multivariate analysis of 136 participants and found that 62.3% had both periodontal disease and obesity.³⁷ Moreover, the participants with abdominal obesity had 2.4 times greater odds of having periodontal disease (95% CI: 1.01-5.1).³⁷ Similar results were obtained in a case-control study by Suvan et al.; participants showed increased odds of diagnosis of periodontitis if they were overweight (OR = 2.56, 95% CI 1.210-5.400) or obese (OR = 3.11, 95% CI 1.052-6.481), compared to normal weight individuals.³⁸ Furthermore, a systematic review investigating the association between obesity and periodontal disease also showed consistent

results, with a pattern of increased risk of periodontitis among overweight and obese individuals.³⁹

2.3 Periodontal Disease and Hyperlipidemia

Like obesity, hyperlipidemia, is a component of MetS associated with both periodontal disease and an increased risk of CVD.⁴⁰ Hyperlipidemia refers to abnormal levels of cholesterol and triglyceride in the blood including hypertriglyceridemia (elevated triglycerides), elevated LDL cholesterol, and reduced HDL cholesterol.⁴⁰ Studies reveal a significant bi-directional relationship between periodontitis and elevated triglycerides, reduced HDL cholesterol, and elevated LDL cholesterol levels.⁴⁰⁻⁴⁵ In a sample size of 33,000 individuals, those with periodontitis had significantly increased odds for having elevated triglycerides in both male and female subjects.⁴¹ Similarly, results by Morita et al. and Sandi et al. found that individuals with elevated triglycerides were much more likely to have periodontal pockets.^{20,22,42} A case-control study conducted in Iran, further supported these findings, as results showed triglyceride levels were significantly higher in periodontal disease patients compared to healthy subjects.⁴³ Elevated levels of serum cholesterol and LDL were also associated with greater odds of periodontal disease.⁴²⁻⁴⁵ The findings of Sandi et al., support this assumption, as patients with chronic periodontitis showed increased serum cholesterol and LDL levels.⁴² Another observational study supported this association, also showing that patients with periodontal disease had reduced levels of HDL and elevated levels of LDL.⁴⁵ Last, in a separate study, low HDL cholesterol was the only MetS component significantly associated with the serum antibody for *Porphyromonas gingivalis*, a marker for periodontal disease.⁴⁴

2.4 Periodontal Disease and Hypertension

Hypertension is one of the most important risk factors for CVD and the most common component of MetS.^{22, 31,34,46,47} Both oxidative stress and endothelial dysfunction are among the critical pathways in the development of hypertension, however, inflammation has increasingly become a recognized contributor.⁴⁶ Many cross-sectional studies propose that the inflammatory response accompanying periodontitis is an important factor that may exert adverse effects on the regulation of blood pressure.^{46,47} Recent studies have shown that both systolic and diastolic blood pressures are higher among periodontal patients than in individuals without periodontitis however, the associations are weaker compared to other MetS components.⁴⁸ According to research by Morita et al., blood pressure was least strongly associated with the presence of periodontal pockets of the five core components of MetS , however the association was still significant.²⁰ Moreover, The Oral Infections and Vascular Disease Epidemiology Study (INVEST) showed a direct relationship between the levels of subgingival periodontal bacteria and hypertension prevalence; the odds ratio for prevalent hypertension was 3.05 (95% CI: 1.60-5.82).⁴⁹ Furthermore, in a study that analyzed data from the Third National Health and Nutrition Examination Survey, a positive linear relationship was demonstrated between systolic BP and severe periodontitis in middle-aged individuals, giving further strength to the association between periodontal disease and hypertension.⁵⁰

2.5 Periodontal Disease and Dysglycemia

According to multiple studies, dysglycemia^h shows the most well-established relationship to periodontal disease.^{8,21,22,51-53} Epidemiological data confirm susceptibility to periodontitis is increased by approximately threefold in people with diabetes.⁵¹ Furthermore, there is emerging evidence to suggest the existence of a two-way relationship between diabetes and periodontitis, with diabetes increasing the risk for periodontitis, and periodontal inflammation negatively affecting glycemic control.⁵¹ In a study of 1,097 subjects, individuals with diabetes mellitus or pre-diabetes had a greater prevalence of periodontal pockets and missing teeth, compared with subjects with normoglycemia.⁵² Furthermore, Morita et al. observed that individuals with elevated fasting plasma glucose and elevated glycosylated hemoglobin levels (a longer-term glucose marker) had increased odds of periodontitis (OR = 1.9 and OR=2.0, respectively).²² The results of a 7 year prospective study assessing the effect of periodontitis on diabetes incidence were supportive of previous findings; specifically, moderate and severe periodontitis were significantly associated with an increased risk of diabetes.⁵³ Furthermore, in a prospective cohort study, type 2 diabetic individuals with severe periodontal disease had 3.2 times the risk of mortality due to ischemic heart disease compared to individuals with no or mild periodontal disease.²¹ Based on study findings, improving glycemic control is likely to reduce the risk and severity of periodontitis in addition to being clinically relevant in the management of related systemic diseases like diabetes.

^h Dysglycemia: broad term referring to an abnormality in blood sugar stability

2.6 Periodontal Therapy and Systemic Disease

Over the last few decades, the association between periodontal disease and MetS has garnered considerable interest among the scientific and medical community. Evidence suggests that periodontal therapy in individuals exhibiting MetS has the potential to reduce the levels of inflammatory mediators in serum and prevent various adverse systemic complications.^{20,21,30-34,53-58} Periodontal therapy involves the removal of plaque and calculus (tartar) by both surgical and non-surgical processes to help restore health to the tissues that support the teeth.⁵⁴ Studies show that periodontal therapy may improve glycemic control and lipid profiles in type 2 diabetics by reducing glycosylated hemoglobin levels.^{30-34,53-58} Moreover, a bidirectional relationship is proposed, such that, treatment of diabetes may actually improve periodontal status.^{30-34,53-58} A prospective cohort study of 628 subjects revealed type 2 diabetic individuals with severe periodontal disease had a 3.2 times greater mortality risk compared with individuals with no or mild periodontitis.²¹ In a randomized controlled trial of periodontal patients assigned to different periodontal therapies, systolic blood pressure ($p < .05$) and triglycerides ($p < .05$) were significantly reduced overall.⁵⁹ Moreover, the number of participants that met the requirements for MetS (27%) was reduced to 14.5%, 17.3%, and 21.8% at three months, six months, and twelve months respectively, post-therapy.⁵

2.7 Periodontal Disease and General Wellness

Periodontal medicine has allowed for further investigation of the association between periodontal disease and MetS, and the demand for increased cooperation between dentists and medical doctors to provide optimal screening, treatment, and prevention of both periodontitis and its comorbidities.³¹ Present studies display a coherent relationship between periodontitis

and MetS, such that, subjects displaying several components of MetS should be referred for periodontal examination, and those with periodontal disease should be evaluated for MetS and its underlying conditions.^{18,19} Integrated clinical care would potentially improve both oral and general health outcomes.^{8,18}

Chapter III-Methodology

3.1 Study Design

A cross-sectional analysis was conducted on the U.S. adult population to explore the association between periodontal disease, MetS, and each component of MetS. The sample population was derived from a secondary database, the 2013-2014 National Health and Nutrition Examination Survey (NHANES); which uses complex and multi-stage, probability sampling to select participants representative of the civilian, and non-institutionalized U.S. population.⁶¹ Oversampling of certain population subgroups was also done to increase the reliability and precision of health status indicator estimates for these groups.⁶¹

The 2013-2014 NHANES survey was selected as the database of choice because it is the most recent survey completed with an oral health exam and full periodontal examination. Oral health data collection protocols were approved by the Centers for Disease Control and Prevention (CDC), National Center for Health Statistics, National Center for Chronic Disease Prevention and Health Promotion, and National Institute of Dental and Craniofacial Research.⁶² Moreover, the periodontal assessment and questionnaire were developed in collaboration with the American Academy of Periodontology (AAP) and the Centers for Disease Control Periodontal Disease Surveillance Workgroup.⁶²

All periodontal examinations were conducted in a mobile examination center (MEC) by licensed dentists in 2013–2014, and data were recorded separately by a separate dental recorder.

The technical details of the survey, including sampling design, periodontal data collection protocols, and data availability can be accessed at: www.cdc.gov/nchs/nhanes.htm.-

The oral health questionnaire used to assess subjects can be retrieved from:

https://wwwn.cdc.gov/nchs/data/nhanes/2013-2014/questionnaires/OHQ_H.pdf,

while the details of the oral health procedures conducted can be found:

https://wwwn.cdc.gov/nchs/data/nhanes/2013-2014/manuals/Oral_Health_Examiners.pdf.

Data assembly was accomplished using SAS 9.4 (Statistical Analysis System, Cary, NC, USA).

Eligibility Criteria

Adults ≥ 30 years of age who participated in the 2013-2014 NHANES were included in the study. Due to the potential risks associated with a full-mouth periodontal examination, participants with conditions that are associated with the highest risk of adverse outcome from endocarditis as identified by the American Dental Association in partnership with the American Heart Association, were excluded.⁶²

Defining Periodontal Disease

For the purposes of epidemiological research, periodontal disease is defined very specifically using the CDC-AAP guidelines. Case definitions for surveillance consider two types of clinical periodontal measurements: attachment loss and pocket depth. For this study, the prevalence of periodontal disease was determined in persons with at least one periodontal site with 3 millimeters or more of calculated attachment loss and 4 millimeters or more of pocket depth (excluding all 3rd molars).⁶⁴ For the NHANES periodontal examination, examiners made two measurements at each periodontal site: one for gingival recession (distance between the free gingival margin and the cemento-enamel junction) and the second for probing pocket depth (distance from the free gingival margin to the bottom of the sulcus or periodontal pocket).

Calculated attachment loss was achieved using the difference between gingival recession and probing pocket depth.⁶²⁻⁶⁵

Defining Metabolic Syndrome and the Metabolic Risk Factors

The International Diabetes Federation (IDF) criteria were used to determine the prevalence of MetS. These criteria were selected because they address both clinical and research needs and provide a comprehensive list of criteria including ethnic specific cut-off points. According to the IDF definition, to be diagnosed as having MetS, a person must have central (abdominal) obesity together with any two of the following risk factors: elevated triglycerides, reduced HDL cholesterol, elevated blood pressure, or elevated fasting plasma glucose.¹¹

Central obesity and reduced HDL cholesterol status was determined for male participants if they had a waist circumference ≥ 102 cm and an HDL cholesterol reading of < 40 mg/dL; for female participants, they were required to have a waist circumference ≥ 88 cm and an HDL cholesterol reading of < 50 mg/dL. Elevated triglyceride status was determined for any participant having triglycerides ≥ 150 mg/dl or specific treatment for this lipid abnormality. Elevated blood pressure was determined for any participant with an average systolic blood pressure reading ≥ 130 or a diastolic blood pressure ≥ 85 mm Hg or treatment of previously diagnosed hypertension. Elevated fasting plasma glucose (EFG) status was determined for any participant with a fasting plasma glucose (FPG) ≥ 100 mg/dL or an oral glucose tolerance test (OGTT) ≥ 100 mg/DL or previously diagnosed type 2 diabetes.

Categorizing Participant Characteristics

Age was reported as the age in years at the time of participation. Participants were distributed across three age categories: adults (30-45) years, middle-aged (46-65) years, and seniors (65 years or greater).

Gender of the participants was reported as the self-reported identification at the time of the screening.

Race/ Ethnicity was classified into four categories: (1) Non-Hispanic White, (2) Hispanic, (3) Non-Hispanic Black and (4) Other. The “Hispanic” category combined Mexican-American and other Hispanic populations as one group, while the “Other” category combined multi-racial and other populations as one group.

Education was classified into three categories: (1) less than high school or high school graduate equivalent, (2) greater than high school and some college, and (3) college graduate or greater. Those with an associate degree were included in the “greater than high school and some college” category while those with a bachelor’s degree or greater were included in the “college graduate or greater” category.

Poverty to income ratios status was based on family income relative to the poverty threshold and used to measure socioeconomic status. Based on the Federal Poverty Guidelines for 2014, participant’s poverty-to-income ratio was classified into three categories: (1) <1.00, (2) 1.00-4.00, and (3) >4.00.⁶⁶ Participants with a ratio of 1.00 have an income below the federal poverty level, participants with a ratio between 1.00-4.00 have low-middle incomes, and those above 4.00 have middle-upper incomes.

Insurance status of participants was self-reported as “yes” or “no” to the question: “Are you covered by health insurance or some other kind of health care plan-includes health insurance obtained through employment or purchased directly as well as government programs like Medicare and Medicaid that provide medical care or help pay medical bills?”

3.2 Statistical Analysis

In the 2013-2014 NHANES, 14,332 persons were selected to participate from 30 different survey locations. Of those selected, 10,175 completed the interview and 9,813 were examined.⁶⁷ For the requirements of this analysis and after applying MEC examination weights, to adjust for the effects of the sampling design, including the unequal probability of selection, the total sample consisted of 1,813 participants.

Descriptive statistics were conducted for selected demographic participant characteristics (age, gender, race/ethnicity, education, poverty-to-income ratio, health insurance status) and clinical measurements (body waist circumference, fasting plasma glucose, blood pressure, triglyceride levels, HDL cholesterol level, periodontal disease, MetS) and bivariate analyses were conducted using Chi-Square Test for categorical variables and the Wilcoxon Rank sum test for continuous variables. Moreover, multivariable logistic regression models were constructed to explore the relationship between body waist circumference, fasting plasma glucose, blood pressure, triglycerides, cholesterol, periodontal disease, MetS and periodontal disease. The results for the logistic regression models were reported as odd ratios (OR) along with their respective 95% confidence interval (CI). The final models (6 total) were fitted by

potential confounders identified by the bivariate analysis. The significance of prevalence differences and odds ratios were assessed with an alpha level of 0.05.

Chapter IV-Results

4.1 Descriptive Statistics

In total, 1,813 participants were eligible for the study. Of the total 1,813 participants, 1,109 had information for periodontal disease and 1,761 for MetS; participants with missing data on the variable of interest were excluded in the analysis.

Periodontal Disease Characteristics

Of the eligible participants, 608 (50.62%) had periodontal disease while the remaining 501 (49.38%) did not have the disease. Among these, 50.18% were female and 49.82% were male. Periodontal disease prevalence was highest among seniors (aged 65+) , followed by middle-aged adults (aged 46-65), and adults ages 30 to 45. Moreover, the prevalence of periodontal disease was highest among racial and ethnic minorities (non-Hispanic Blacks, Hispanics, and other, respectively), those with an education less than or equivalent to high school (71.36%), those with a poverty to income ratio < 1.00 (65.62%), and those with no health insurance (65.33%). In addition, the prevalence of periodontal disease was found to be greater in participants having central obesity (50.17%), elevated fasting plasma glucose (51.39%), elevated blood pressure (54.71%), reduced HDL cholesterol (52.06%), and metabolic syndrome (50.34%).

Metabolic Syndrome Characteristics

In contrast to periodontal disease, the majority of participants (994, 57.12%) did not have MetS compared to those who did (767, 42.88%). Among these, 48.06% were female and 51.94% were male. The prevalence of MetS was highest among seniors (aged 65+), followed by middle-

aged adults (aged 46-65), followed by adults ages 30 to 45. The prevalence of MetS was highest among non-Hispanic Whites (45.31%), followed by non-Hispanic Blacks (43.33%), followed by Hispanics (39.99%), followed by other races (23.55%). Among those with an education greater than high school/some college(49.00%), a poverty to income ratio between 1.00 and 4.00 (47.26%), health insurance (45.07%) and periodontal disease(40.67), the prevalence of MetS was also the highest.

4.2 Result of Bivariate Analysis

Periodontal Disease and Participant's Characteristics

Statistically significant associations were found between periodontal disease and all the selected participant demographic characteristics including age ($P<.0001$), gender ($P=0.001$), race/ethnicity ($P<.0001$), education ($P<.0001$), poverty-to-income ratio ($P<.001$), and health insurance ($P<.0001$). In contrast, the only component of MetS that had a statistically significant association determined with periodontal disease was elevated blood pressure ($P=0.0035$) (See Tables 1.1 and 1.2).

Metabolic Syndrome and Participant's Characteristics

Statistically significant associations were found between MetS and all selected participant demographic characteristics: age ($P<.0001$), gender ($P=0.0077$), race/ethnicity ($P<.0001$), education ($P<.0001$), poverty-to-income ratio ($P=0.0047$), and health insurance ($P=0.0013$). However, the association between MetS and periodontal disease was not significant ($P=0.6334$) (See Table 1.3).

4.3 Result of Multivariate Analysis

Unadjusted Odds Ratios

In the unadjusted models, under replicated and identical studies: The odds of observing periodontal disease in the population aged 65+ is 2.976 the odds of observing periodontal disease in the population aged between 30 and 45; 95% of the time, the odds ratio will be between 1.958-4.522. The odds of observing periodontal disease in the men is 1.573 the odds of observing periodontal disease in women; 95% of the time, the odds ratio will be between 1.201-2.059. The odds of observing periodontal disease in non-Hispanic Blacks is 2.309 the odds of observing periodontal disease in non-Hispanic Whites; 95% of the time, the odds ratio will be between 1.354-3.938. The odds of observing periodontal disease among those with \leq high school is 3.791 the odds of observing periodontal disease in those with an education $>$ college; 95% of the time, the odds ratio will be between 2.484-5.784. The odds of observing periodontal disease among those with a poverty-to-income ratio <1.00 is 1.915 the odds of observing periodontal disease in those with a poverty-to-income ratio ≥ 1.00 -4.00; 95% of the time, the odds ratio will be between 1.218-3.011. The odds of observing periodontal disease among those with a poverty-to-income ratio >4.00 is 0.765 the odds of observing periodontal disease in those with a poverty-to-income ratio ≥ 1.00 -4.00; 95% of the time, the odds ratio will be between 0.605-0.968. The odds of observing periodontal disease among those with no health insurance is 2.177 the odds of observing periodontal disease in those with health insurance; 95% of the time, the odds ratio will be between 1.413-3.353. (See Tables 1.1 and 1.2).

Adjusted Odds Ratios

In the adjusted models, under replicated and identical studies and controlling for age, gender, race/ethnicity, education, poverty-to-income ratio, and health insurance: The odds of observing periodontal disease in centrally obese participants is 1.045 the odds of observing periodontal disease in non-centrally obese participants; 95% of the time, the odds ratio will be between 0.791-1.379. The odds of observing periodontal disease in participants with elevated fasting plasma glucose is 0.835 the odds of observing periodontal disease in participants with normal elevated fasting plasma glucose; 95% of the time, the odds ratio will be between 0.522-1.534. The odds of observing periodontal disease in participants with elevated blood pressure is 1.172 the odds of observing periodontal disease in participants with normal blood pressure; 95% of the time, the odds ratio will be between 0.821-1.674. The odds of observing periodontal disease in participants with elevated triglycerides is 0.835 the odds of observing periodontal disease in participants with normal triglycerides; 95% of the time, the odds ratio will be between 0.550-1.269. The odds of observing periodontal disease in participants with reduced HDL cholesterol is 0.984 the odds of observing periodontal disease in participants with normal HDL cholesterol; 95% of the time, the odds ratio will be between 0.571-1.697. The odds of observing periodontal disease in participants with MetS is 0.885 the odds of observing periodontal disease in participants with no MetS; 95% of the time, the odds ratio will be between 0.607-1.288 (See Table 2.1).

Chapter V-Discussion

5.1 Discussion

The purpose of this analysis was to explore the associations between periodontal disease, MetS, and the five metabolic risk factors (hypertension, reduced HDL cholesterol, abdominal obesity, elevated blood glucose levels, and elevated triglycerides) among the United States adult population. To be diagnosed with MetS, one must have had at least three of the five metabolic risk factors (defined by the IDF criteria), and to be diagnosed with periodontal disease, one must have had at least one periodontal site with 3 millimeters or more of calculated attachment loss and 4 millimeters or more of pocket depth (excluding all 3rd molars).^{9-11,64} The results of this analysis suggest limited and inconclusive evidence for the associations of interest.

For both MetS and periodontal disease, statistically significant associations were observed in specific participant demographic characteristics. These findings are consistent with previous studies showing that the prevalence of periodontitis ranked highest among racial and ethnic minorities, men, adults aged 65 and older, and those with less than a high school education.^{14,19} The added elements of health insurance and poverty-to-income ratio gave insight to the potential impact socioeconomic status has on health outcomes, by also yielding statistically significant associations with lack of health insurance and lower income levels. In “Oral Health: The Silent Epidemic,” former U.S. Surgeon General Regina Benjamin reports that a striking 25% of adults ages 65 and older have lost all of their teeth due to untreated oral disease, and that health disparities related to access to proper dental care may be responsible.¹⁸ According to the data from Dr. Benjamin, oral health diseases disproportionately affect disadvantaged communities.^{18,69-71} Moreover, the findings of this study are also consistent with

previous analyses showing that oral health and dental disease are closely associated with income and education.^{18,19,69-71}

Despite existing evidence to suggest a bidirectional relationship between periodontal disease and MetS, and positive associations between periodontal disease and the five metabolic risk factors, no statistically significant associations were demonstrated in this analysis.²¹ These findings are not consistent with previous research, suggesting differences may be subject to systemic error and variable selection. For instance, the defining criteria for metabolic syndrome may have been too selective compared to other studies and the defining criteria for periodontal disease may have been too vague. Moreover, perhaps the associations become statistically significant when considering the extent or severity of periodontal disease.¹⁹ The only significant association observed was between periodontal disease and hypertension, which has been demonstrated to be relevant, however, weaker, compared to other MetS components.⁴⁸

While the associations between hypertension, reduced HDL cholesterol, abdominal obesity, elevated blood glucose levels, elevated triglycerides and periodontal disease in this analysis were not statistically significant, it is important not to overlook that both the outcome and predictors were significantly associated with age, gender, race/ethnicity, education level, poverty-to-income ratio, and health insurance status. These results imply that while no evidence was found to support a link between periodontal disease and metabolic syndrome or periodontal disease and the five metabolic risk factors, they are strongly associated with socioeconomic status. These findings emphasize the prevalence of health disparities among populations with lower socioeconomic status, and the importance of targeting resources and interventions to these communities of greatest need.

5.2 Study Limitations

Due to the cross-sectional nature of the study, this analysis has several limitations. For instance, we are unable to infer causal relationships because the presence of risk factors (MetS, hypertension, reduced HDL, abdominal obesity, elevated blood glucose levels, elevated triglycerides) and outcome (periodontal disease) were measured simultaneously. Cross-sectional studies measure prevalent rather than incident cases during a specific point (snapshot) in time, therefore the information is not guaranteed to be predictive. Moreover, collection of information about risk factors was retrospective, running the risk of recall bias; recoding and deleting non-responses can also result in bias in measurements and outcomes. In addition, the criteria used to define periodontal disease, MetS, and each risk factor may differ across studies and skew results to show stronger or weaker associations.

5.3 Implications of Findings

As awareness of the barriers to access to oral healthcare and its importance in overall health grows, dentists, physicians, and other health professionals have begun to extend their support for the integration of oral disease prevention strategies into chronic disease prevention.^{68,72,73} There is a strong body of evidence today suggesting that periodontitis is likely to increase the risk of systemic diseases, much like periodontal therapy may improve coexisting chronic conditions.¹⁸⁻⁶⁰ Moreover, there is evidence to support a bidirectional relationship such that comorbidities may increase the risk of periodontal disease and managing comorbidities may improve oral health.¹⁸⁻⁶⁰ Introducing interprofessional education to medical and dental students would be an important step forward in producing clinicians knowledgeable about the

connections between oral health and systemic diseases. By integrating oral and physical health care, we can help optimize optimal screening, treatment, and prevention of both periodontitis and comorbidities, reducing overall morbidity and mortality.

5.4 Conclusion

In the words of former Surgeon General Regina Benjamin, oral health “supports and reflects” the health of the entire body and is a “gateway” to general health and well-being.¹⁸ Proper oral health is vital to a productive and healthy life. By understanding the risk factors associated with systemic diseases we are able to improve the quality of our increasing longevity and reduce the burden of disease for current and future generations. Based on the literature, there is a need for population-based action to prevent periodontitis and develop improved models for the integration of medical and dental healthcare. This is especially important for disadvantaged populations—those with less education, lower incomes, and a lack of health insurance coverage—that suffer a disproportionate burden of metabolic syndrome, its associated conditions, and periodontal disease. The present study presents an overview of the evidence linking periodontitis with selected systemic diseases and calls for increased coordination between dental and medical providers to provide optimal screening, treatment, and prevention of both periodontitis and its comorbidities. This study’s failure to demonstrate a significant association between periodontal disease, MetS, and the five metabolic risk factors, leaves an open invitation for additional research.

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Table 1.1 Descriptive Statistics and Odds Ratios for the Association Between Periodontal Disease and Participant Demographics

Participant Characteristics	PD ^A N(%)=608 (49.38%)	No PD ^A N(%)=501 (50.62%)	Total ^B N(%)=1109	P-value	Crude OR (95% CI)
Demographics					
Age					
30-45	236 (44.48%)	244 (55.52%)	480 (45.49%)	<.0001 ^C	1.00 ^D
46-65	255 (47.76%)	202 (52.24%)	457 (40.78%)		1.141 (0.793-1.642)
>65	117 (70.45%)	55 (29.55%)	172 (13.73%)		2.976 (1.958-4.522)
Gender					
Female	275 (43.77%)	279 (56.23%)	554 (50.18%)	0.001 ^C	1.00 ^D
Male	333 (55.04%)	222 (44.96%)	555 (49.82%)		1.573 (1.201-2.059)
Race/Ethnicity					
Hispanic	151 (59.61%)	95 (40.59%)	246 (13.20%)	0.0001 ^C	1.00 ^D
NH-White	243 (44.47%)	271 (55.53%)	514 (69.67%)		1.843 (1.094-3.104)
NH-Black	120 (64.91%)	59 (35.09%)	179 (10.01%)		2.309 (1.354-3.938)
Other	94 (56.63%)	76 (43.37%)	170 (7.12%)		1.631 (0.928-2.866)
Education					
≤ HS	127 (71.36%)	56 (68.64%)	183 (11.51%)	<.0001 ^C	3.791 (2.484-5.784)
>HS/Some College	307 (51.80%)	240 (48.20%)	547 (50.01%)		1.635 (1.261-2.120)
>College	174 (39.66%)	205 (60.34%)	379 (38.48%)		1.00 ^D
PIR					
<1.00	127 (65.62%)	56 (34.38%)	183 (12.23%)	<.0001 ^C	1.915 (1.218-3.011)
≥ 1.00-4.00	273 (50.04%)	232 (49.96%)	505 (45.93%)		1.00 ^D
>4.00	167 (43.49%)	187 (56.51%)	354 (41.85%)		0.765 (0.605-0.968)
Insurance					
Yes	458 (46.39%)	432 (53.61%)	890 (84.21%)	<.0001 ^C	1.00 ^D
No	150 (65.33%)	69 (34.67%)	219 (15.79%)		2.177 (1.413-3.353)

Abbreviations: PD, Periodontal Disease; OR, Odds Ratio; CI, Confidence Interval; NH, Non-Hispanic; HS, Highschool; PIR, Poverty to Income Ratio

A:Row-percent

B:Column-percent

C:Chi-Square statistical test was used to test for association.

D. Referent category

*p-value highlighted in bold indicates the finding is statistically significant at $\alpha=0.05$ ($p<.05$)

Table 1.2 Descriptive Statistics and Odd Ratios for the Association Between Periodontal Disease
and Clinical Examination

Participant Characteristics	PD ^A N(%)=608 (49.38%)	No PD ^A N(%)=501 (50.62%)	Total ^B N(%)=1109	P-value	Crude OR (95% CI)
Clinical Information					
Body Waist Circumference, cm					
Normal	263 (48.01%)	215 (51.99%)	478 (41.42%)	0.3625 ^C	1.00 ^D
Central Obesity	335 (50.17%)	278 (49.83%)	613 (58.58%)		1.090 (0.892-1.333)
Fasting Plasma Glucose, mg/dL					
< 100	210 (46.51%)	199 (53.49%)	409 (41.14%)	0.3795 ^C	1.00 ^D
≥100	398 (51.39%)	302 (48.61%)	700 (58.86%)		1.216 (0.754-1.959)
Blood Pressure, mmHg					
Normal	292 (44.87%)	283 (55.13%)	575 (54.15%)	0.0035 ^C	1.00 ^D
Elevated	316 (54.71%)	218 (45.29%)	534 (45.85%)		1.484 (1.087-2.026)
Triglyceride, mg/dL					
<150	447 (49.58%)	377 (50.42%)	824 (73.84%)	0.8356 ^C	1.00 ^D
≥ 150	157 (48.67%)	122 (51.33%)	279 (26.16%)		0.965 (0.665-1.398)
HDL Cholesterol					
Normal	353 (47.48%)	314 (52.53%)	667 (58.94%)	0.3532 ^C	1.00 ^D
Reduced	252 (52.06%)	185 (47.94%)	437 (41.06%)		1.015 (0.655-1.574)
Metabolic Syndrome					
No	362 (48.57%)	304 (51.43%)	666 (60.19%)	0.6334 ^C	1.00 ^D
Yes	236 (50.34%)	189 (49.66%)	425 (39.81%)		1.074 (0.780-1.477)

Abbreviations: PD, Periodontal Disease; OR, Odds Ratio; CI, Confidence Interval; NH, Non-Hispanic; PIR, Poverty to Income Ratio

A: Row-percent

B: Column-percent

C: Chi-Square statistical test was used to test for association.

D. Referent category

*p-value highlighted in bold indicates the finding is statistically significant at $\alpha=0.05$ ($p < .05$)

Table 1.3 Descriptive Statistics and Odds Ratios for the Association Between Metabolic

Syndrome and Participant Demographics

Participant Characteristics	MetS ^A N(%)=767 (42.88%)	No MetS ^A N(%)=994 (57.12%)	Total ^B N(%)=1761	P-value
Demographics				
Age				
30-45	171 (30.57%)	409 (69.43%)	580 (36.29%)	<.0001 ^C
46-65	346 (45.92%)	399 (54.08%)	745 (42.94%)	
>65	250 (58.10%)	186 (41.90%)	436 (20.77%)	
Gender				
Male	321 (38.38%)	540 (61.62%)	861 (48.06%)	0.0077 ^C
Female	446 (47.05%)	454 (52.95%)	900 (51.94%)	
Race/Ethnicity				
Hispanic	170 (39.99%)	228 (60.01%)	398 (37.45%)	<.0001 ^C
NH-White	391 (45.31%)	416 (54.69%)	807 (68.48%)	
NH-Black	157 (43.33%)	165 (56.67%)	322 (11.38%)	
Other	49 (23.55%)	185 (76.45%)	234 (6.90%)	
Education				
≤ HS	188 (45.55%)	218 (54.45%)	406 (26.04%)	<.0001 ^C
>HS/Some College	430 (49.00%)	450 (51.00%)	880 (51.05%)	
>College	148 (31.86%)	326 (64.14%)	474 (32.43%)	
PIR				
<1.00	163 (43.97%)	184 (56.03%)	347 (15.18%)	0.0047 ^C
≥ 1.00-4.00	395 (47.26%)	452 (52.74%)	847 (48.44%)	
>4.00	161 (36.97%)	291 (63.03%)	452 (36.38%)	
Insurance				
No	108 (31.48%)	231 (68.52%)	339 (16.12%)	0.0013 ^C
Yes	658 (45.07%)	762 (54.93%)	1420 (83.88%)	
Clinical Information				
Periodontal Disease				
No	189 (38.97%)	304 (61.03%)	493 (50.73%)	0.6334
Yes	236 (40.67%)	362 (59.33%)	598 (49.27%)	

Abbreviations: MetS, Metabolic Syndrome; NH, Non-Hispanic; HS, Highschool; PIR, Poverty to Income Ratio

A:Row-percent

B:Column-percent

C:Chi-Square statistical test was used to test for association.

*p-value highlighted in bold indicates the finding is statistically significant at $\alpha=0.05$ ($p<.05$)

Table 2.1 Adjusted Odds Ratios for the Associations Between Periodontal Disease and Body Waist Circumference, Fasting Plasma Glucose, Blood Pressure, Triglycerides, HDL Cholesterol, and MetS

Participant Characteristics	Adjusted OR (95% CI)
Body Waist Circumference, cm (Model 1)	
Normal	1.00 ^A
Central Obesity	1.045 (0.791-1.379)
Fasting Plasma Glucose, mg/dl (Model 2)	
< 100	1.00 ^A
≥100	0.895 (0.522-1.534)
Blood Pressure, mmHg (Model 3)	
Normal	1.00 ^A
Elevated	1.172 (0.821-1.674)
Triglyceride, mg/dl (Model 4)	
<150	1.00 ^A
≥ 150	0.835 (0.550-1.269)
HDL Cholesterol (Model 5)	
Normal	1.00 ^A
Reduced	0.984 (0.571-1.697)
Metabolic Syndrome (Model 6)	
No	1.00 ^A
Yes	0.885 (0.607-1.288)

Abbreviations: OR, Odds Ratio; CI, Confidence Interval

**Adjusted model 1 included the following covariates: Age, Race, Gender, Education PIR, Insurance, and Body Waist Circumference

**Adjusted model 2 included the following covariates: Age, Race, Gender, Education PIR, Insurance, and Fasting Plasma Glucose

**Adjusted model 3 included the following covariates: Age, Race, Gender, Education PIR, Insurance, and Blood Pressure

**Adjusted model 4 included the following covariates: Age, Race, Gender, Education PIR, Insurance, and Triglycerides

**Adjusted model 5 included the following covariates: Age, Race, Gender, Education PIR, Insurance, and HDL Cholesterol

**Adjusted model 6 included the following covariates: Age, Race, Gender, Education PIR, Insurance, and Metabolic Syndrome

A:Referent Category